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Seed Treatments for Corn, Oats, and Barley in Arkansas

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SEED TREATMENTS FOR CORN, OATS, AND BARLEY IN ARKANSAS

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Standard treatments for the control of diseases of small grains and corn have resulted in their widespread use throughout much of the United States, but their application to conditions in Arkansas and the other cotton-growing states is probably less understood than in any other section of the country. Since farmers of the cotton areas have been, until comparatively recently, interested in small grains only in a minor way, it was to be expected that less attention would be paid to the control of cereal diseases than in regions where cereals are the predominating crops.[1]

The development of seed treatments for corn resulted originally from the difficulties encountered in cooler regions where seedling diseases, favored by the cool, wet weather of spring, are often a serious obstacle to the securing of satisfactory stands, but the question of their value under Southern conditions arose so frequently that a genuine need for information regarding their value under Southern conditions was apparent.

SEED-CORN TREATMENTS

Work conducted by Kiesselbach *(1, 2)* and Kiesselbach and Culbertson *(3)* in Nebraska, prior to the work at the Arkansas station, indicated little benefit from the treatments used on seed corn. Melchers and Brunson *(4)* report no benefit from corn-seed treatments in Kansas, and Wedgeworth, *et al., (5)* in Mississippi found little or no benefit from organic mercury treatments for seed corn when precautions were taken to select sound ears for seed. In general, it may be said that the greatest benefit from corn-seed treatments has been found in Illinois, Iowa, and the surrounding states.

Methods

Experiments with corn-seed treatments were conducted 4 years out of 5 during the period, 1928 to 1932, at the Main Experiment Station, on Clarksville silt loam soil of rather low fertility.

[1] The data on corn-seed treatments appeared previously in the Journal of the American Society of Agronomy, Vol. 26, No. 3, 1934, and the data on oats-seed treatments for 1930 and 1931 appeared previously in Phytopathology Vol. 23, No. 10, 1933. Other results have not been published previously.

Neal's Paymaster corn was used. No attempt was made to select diseased seed, because it was believed that unless the treatments were beneficial for average, good-quality seed they would be of little practical value. The seed was treated by agitating the seed and fungicidal dust in a closed container until all seeds were thoroughly coated with the dust. Fungicides were used that had been recommended by various workers for seed-corn treatment, and they were used as recommended by the manufacturers. Seed was planted by hand at the rate of two kernels per hill, and, after stand counts had been obtained, the plants were thinned to one plant per hill.

1928 Studies

Neal's Paymaster seed was treated with Bayer Dipdust (active ingredients, hydroxymercurichlorophenol sulphate) and Semesan, Jr. (active ingredient, 12 per cent hydroxymercuricresol) at the rate of 3 ounces per bushel. Each plot consisted of 21 rows 132 feet long, and was equivalent to 0.233 acre. There were four series of each treatment and five checks, making a total of 13 plots. Seed was planted on May 7, a medium planting date for the locality. The land was cultivated according to standard practices at the Main Experiment Station farm, and on June 2, 1928, data on germination were obtained by counting the number of plants in 10 rows on each plot. Yield records were obtained by weighing the corn obtained from every three rows, thus giving seven weights per plot. The data on germination and yield of corn as influenced by dust seed treatments in 1928 are presented in Table 1.

The effect of Dipdust on the stand was slight and of no significance. On the other hand, the first stands on the plots treated

Table 1. Effects of Seed Treatments on Stand and Yield of Corn, Main Experiment Station, 1928

Item	No seed treatment	Seed treatment	
		Dipdust	Semesan Jr.
Average number of plants per row	131.3 ± 0.712	129.3 ± 0.78	120.0 ± 0.991
Differences		−2.0 ± 1.05	−11.3 ± 1.22 [1]
Mean yield, bushels per acre	59.4 ± .73	61.33 ± .77	58.97 ± 1.456
Differences		1.93 ± 1.02	− .43 ± 1.630

[1] Significant differences.

with Semesan Jr. were significantly lower than those of the checks. Confidence can be placed in the lack of significant differences in yield, the probable errors having been determined from 28 three-row plots planted with treated seed and from 35 such plots planted with nontreated seed.

1929 Studies

In 1929 Sterocide, the active principle of which is said to be mercury furfuramide, was substituted for Dipdust. This was applied at the rate of 2 ounces per bushel. Since work in the Northern States had emphasized the fact that seed treatments may protect seed corn from decay during periods of cold weather when germination is retarded and certain cold-tolerating fungi are active, it was decided to test the effect of seed treatments on early, medium, and late plantings. Neal's Paymaster corn was again used. The dates of planting were April 25, May 20, and June 15, the time interval being about 25 days. Seed was treated in the manner previously described. Three replications of the treatments were made in each planting, there being 10 rows per plot.

Counts of plants were again made to note the effect of the dust treatments upon the germination. Later the corn was thinned to one stalk per hill. The results are summarized in Table 2.

Table 2. Effect of Seed Treatments on Stand and Yield of Corn, Main Experiment Station, 1929

Item	No seed treatment	Seed treatment	
		Sterocide	Semesan Jr.
Planted April 25			
Average number of plants per row	98.73 ± 0.428	105.87 ± 0.419	107.60 ± 0.353
Differences [1]		7.14 ± .600 [2]	8.87 ± .550 [2]
Mean yield, bushels per acre	12.40 ± .774	19.17 ± .524	16.03 ± .622
Differences [1]		6.77 ± .930 [2]	3.63 ± .990 [2]
Planted May 20			
Average number of plants per row	115.60 ± .342	123.93 ± .292	115.27 ± .585
Differences [1]		8.33 ± .450 [2]	— .33 ± .670
Mean yield, bushels per acre	14.62 ± .456	15.76 ± .719	15.27 ± .814
Differences [1]		1.14 ± .850	.65 ± .930
Planted June 15			
Average number of plants per row	128.93 ± .352	125.40 ± .448	125.80 ± .262
Differences [1]		—3.53 ± .570 [2]	—3.13 ± .440 [2]
Mean yield, bushels per acre	10.16 ± .482	10.23 ± .442	8.81 ± .400
Differences [1]		.07 ± .650	—1.35 ± .620

[1] Differences in comparison with check.
[2] Significant difference.

The results show significant and consistent increases in the number of plants in the early plantings from use of the treatments, and consistent and significant decreases from their use in the late plantings. At the medium date the results were variable, Sterocide giving a significant increase in number of plants, and Semesan Jr. no marked difference.

In early plantings the beneficial results of seed treatments to the stand were followed by significant yield increases. In the medium and late plantings differences in yield were not significant.

1930 Studies

In 1930 seed treatments with Semesan Jr. and Sterocide were again made. The corn was planted April 16, May 7, and May 25, planting two seeds per hill. After stand counts were made, the plants were thinned to one plant per hill. The results are presented in Table 3.

In the early planting, contrary to expectation and very much contrary to results of 1929, the number of plants from nontreated seed was significantly greater than those from treated seed. In the May 7 planting nontreated seed and seed treated with Semesan Jr. resulted in better germination counts than seed treated with Sterocide, though the difference between the Sterocide and Semesan Jr. treatments was not significant. In the May 25 plant-

Table 3. Effect of Seed Treatments on Stand and Yield of Corn, Main Experiment Station, 1930

Item	No seed treatment	Seed treatment	
		Sterocide	Semesan Jr.
Planted April 16			
Average number of plants per row [1]	138.7 ± 0.788	129.8 ± 0.833	131.0 ± 1.179
Differences		−8.9 ± 1.146 [2]	−7.7 ± 1.418 [2]
Average yield per 10 rows *Pounds*	66.7	88.3	85.5
Planted May 7			
Average number of plants per row	117.6 ± 1.501	109.6 ± 1.104	116.6 ± .890
Differences		− .8 ± 1.863 [2]	−1.0 ± 1.745
Average yield per 10 rows *Pounds*	12.9	15.7	9.3
Planted May 25			
Average number of plants per row	109.4 ± 1.860	116.6 ± 1.389	114.2 ± 1.408
Differences		7.2 ± 2.321	4.8 ± 2.322
Average yield per 10 rows *Pounds*	79.0	100.3	95.1
Average number of plants, all rows	121.9	118.7	120.6
Average yield all plants, per acre *Bushels*	6.8	8.8	8.2

[1] Averages of 24 to 30 rows.

[2] Significant differences.

ing, contrary again to results of 1929, the nontreated seed gave the lowest average number of plants per row, but the differences were not significant when the probable error was considered.

Because 1930 was a drought year, any statistical constants that might be calculated from the yield data would be of little value from the seed-treatment standpoint.

1932 Studies

In 1932 Sterocide and Semesan Jr. were again used, and also Merko (the active ingredient of which was said to be an inorganic mercury compound) and Dubay 1100 (active ingredient, 10 per cent ethyl mercury phosphate). There was an average of 72 hills per row, with two kernels being planted in each hill. The number of plants coming up and also the stands after thinning were recorded for each row. The means and errors for each treatment and each date were determined, and also the mean differences from the check for each treatment. The results are presented in Table 4.

On the April 18 planting, no effect of seed treatment on germination, ultimate stand, or yield was obtained from Merko, Dubay 1100, or Sterocide. Semesan Jr. apparently caused some

Table 4. Emergence, Stands, and Yields of Corn Following Seed Treatments, Main Experiment Station, 1932

Treatment	Mean differences between treatments and checks		
	Seedlings per row	Stand after thinning	Corn yield per row
			Pounds
Planted April 18			
Range of means	110 — 122	63 — 67	27.2 — 30.5
Merko	— 2 ± 2.78	—1 ± 0.86	1.4 ± 1.35
Dubay 1100	1 ± 2.94	—1 ± .95	—1.9 ± .92
Sterocide	— 4 ± 2.85	—2 ± .86	.1 ± .81
Semesan Jr.	—11 ± 3.09 [1]	—4 ± 1.25 [1]	1.1 ± .94
Planted May 5			
Range of means	97 — 108	61 — 69	26.1 — 34.9
Merko	— 3 ± 1.91	—1 ± .99	7.9 ± 1.00 [1]
Dubay 1100	8 ± 1.91 [1]	7 ± .78 [1]	5.3 ± 1.22 [1]
Sterocide	6 ± 2.02 [1]	6 ± .75 [1]	3.0 ± 1.40
Semesan Jr.	3 ± 2.07	2 ± .83	— .9 ± 1.34
Planted May 21			
Range of means	115 — 122	67 — 71	28.7 — 32.7
Merko	— 4 ± 2.82	Even	4.4 ± 1.06 [1]
Dubay 1100	— 3 ± 2.32	3 ± 1.33	3.3 ± .97 [1]
Sterocide	3 ± 2.75	4 ± 1.26 [1]	4.0 ± 1.03 [1]
Semesan Jr.	3 ± 2.73	3 ± 1.39	1.0 ± 1.06

[1] Significant differences.

reduction in germination and stand, but there was no reduction in yield. On the May 5 planting, significant increases in germination and stand were obtained from the Dubay 1100 and Sterocide treatments, and an increased yield from the Merko and Dubay 1100 treatments.

On the May 21 planting, there were no significant differences in the germination. The stand was better for Sterocide-treated seed, and yield increases were obtained on all plots except those planted to Semesan Jr.-treated seed.

In two cases (with Dubay 1100 on May 5 and Sterocide on May 21) increases in yields corresponded with an increase in ultimate stand; only the former, however, corresponded with a difference in germination, the gain in yield amounting to 6.8 bushels per acre. The other gains in yields might be attributed to soil variations.

The effect of seed treatments might be felt in two ways, viz., an increased vigor, which might be reflected in the yield, and a better stand, which also might result in better yields. In only two cases did significant increases in yields follow significant differences in ultimate stand (Table 4).

Temperature and Rainfall

The average temperatures and rainfall for both the months and weeks of planting are presented in Table 5. There were very few departures from what would be termed normal conditions.

Weather conditions in the spring of 1928 were as follows: Unusually heavy rainfall in the month preceding planting, and normal temperatures during the month of planting. In 1929 temperatures for April and for the week of planting were somewhat low. On the April planting both Sterocide- and Semesan Jr.-treated seed gave increases in stand and yield. In 1930 and 1932, when temperatures were higher in April, there was a reduction in first stands from both treatments. There is at best only a slight indication that some benefit would accrue from such seed treatments in cold weather.

Discussion of Results

The effects of various dust treatments on germination and yield of seed corn was studied for 4 years within a 5-year period. Neal's Paymaster was used. In 1928 the seed was treated with Dipdust and Semesan Jr., and only one planting was made. No

TABLE 5. AVERAGE TEMPERATURES AND RAINFALL OF PLANTING SEASONS, MAIN EXPERIMENT STATION, 1928-30, 1932

Year	Average monthly temperatures			Rainfall		
	April	May	June	April	May	June
	Degrees F.	*Degrees F.*	*Degrees F.*	*Inches*	*Inches*	*Inches*
1928	54.40	66.00	69.20	10.56	4.56	8.90
1929	61.00	63.70	76.20	6.67	7.50	6.96
1930	63.10	65.10	72.20	2.83	6.88	4.00
1932	62.00	67.50	76.00	2.28	1.71	8.65
	Average temperatures and rainfall for week following each planting [1]					
1928	.....	66.36	.....	.....	0.08	.....
1929	57.30	62.40	75.60	.72	1.03	.40
1930	61.80	66.43	62.36	1.27	1.32	.00
1932	66.43	66.80	73.36	.32	.30	1.31

[1] Dates of planting are given in the preceding tables.

significant gains or losses in either germination or yield resulted from the use of Dipdust. With Semesan Jr. there was some reduction in the number of seedlings, but there was no difference in yield.

In 1929 Sterocide and Semesan Jr. were used, and plantings were made April 25, May 20, and June 15. With the early planting both Sterocide and Semesan Jr. returned significant increases in yields and in the number of seedlings. With the intermediate planting the only effect was a slight increase in number of seedlings from use of Sterocide. In the late planting each treatment caused significant decreases in number of seedlings, with no resultant effect on yield.

In 1930, a year marked by a prolonged drought, Sterocide and Semesan Jr. were again used. Plantings were made April 16, May 7, and May 25. Contrary to results of 1929, both treatments caused significant decreases in number of seedlings in the early planting. Sterocide again caused a decrease in the number of seedlings in the intermediate planting, but produced a significant increase in the late planting. The two earlier plantings yielded much better than the later one, but all yields were abnormally low and statistical treatment of yields was not attempted.

In 1932 Merko, Dubay 1100, Sterocide, and Semesan Jr. were used on plantings made April 18, May 5, and May 21. In addition

to original counts of seedlings, later counts were made after thinning to one stalk. Semesan Jr. reduced the number of seedlings and the ultimate stands, but had no effect upon yields in the early planting. Sterocide gave an increase in seedlings in the intermediate plantings, and improved ultimate stands and yields in both intermediate and late plantings. Dubay 1100 increased the number of seedlings and improved the stand in the intermediate planting, and improved yields in both the intermediate and late plantings. Merko did not affect the stand of any of the three plantings, but it did increase the yield of the two later plantings. It had no significant effect upon the yield of the first planting.

A study of monthly and weekly temperatures of the planting dates, and also of the rainfall, failed to reveal any explanation for the variable results obtained.

Except in 1929, Semesan Jr. caused significant reductions in first stands in all early plantings.

The conclusion must be drawn that, under the conditions of these tests, no assured benefit can be obtained as a result of the use of any of the fungicidal dusts employed.

Summary

Using five fungicidal dusts, the effects of seed treatments on Neal's Paymaster corn were studied for 4 years, 1928, 1929, 1930, and 1932.

Data were taken on total emergence of seedlings, on final stands, and on yields.

There was no correlation between the results and weather conditions during the planting season.

Under the conditions of these tests no assured benefits were obtained as a result of the use of any of the five fungicidal dusts.

OAT-SEED TREATMENTS

Seed-treatment studies with oats were designed primarily for the control of smut, but the work of the last 4 years of the study, 1933-36, had the further objective of determining, if possible, whether there were beneficial effects upon the yields resulting from these treatments other than those that might be attributed to the control of oat smut. The Fulghum variety was employed throughout the study and only spring plantings were

made. Plantings were made on the Main Experiment Station farm on Clarksville silt loam soil of rather low-yielding capacity. The original seed stock was from a very badly smutted plot of Fulghum oats, harvested in 1930, and later plantings were from seed obtained from the treated and nontreated plots of the experimental field. Symptoms and microscopic examination of spores both indicated that loose smut, caused by *Ustilago avenae* (Pers.) Jens., was the principal disease present.

1931-32 Studies

The following fungicidal dusts were applied in 1931: Ceresan, active principle 2 per cent ethyl mercury chloride; Dubay No. 952 K, active principle ethyl mercury tartrate 2 per cent; Dubay No. 952 C, active principle ethyl mercury tartrate one per cent; Dubay No. 500 LL, active principle ethyl mercury arsenate one per cent; Merko, the active ingredient of which is said to be an inorganic mercury compound; Corona Oat Dust, said to be activated formaldehyde; and Corona No. 174 E, said to contain a soluble organic mercury compound. In addition to the dust treatments, seed for one plot in 1931 and for three plots in 1932 was treated with a 10 per cent solution of iodine in carbon bisulphide at the rate of one-half ounce of elemental iodine per bushel. In 1932 Dubay No. 1134, active principle ethyl mercury phosphate 2.5 per cent, and the liquid-formaldehyde treatment[2] were added to the tests. Merko, which failed to control oat smut in 1931, and Corona No. 174 E, which was less effective than the other dusts employed in 1931, were not used in 1932.

Dusts were applied by means of a barrel churn to which a baffle plate had been added at one end in order to obtain more thorough mixing. The churn was rotated for 5 minutes. The interior of the churn was washed and dried after each treatment. Dusts were applied at the rate of 3 ounces per bushel except Dubay No. 1134, which was applied at the rate of one ounce per bushel, according to the recommendation of the manufacturers. The iodine in carbon-bisulphide solution was added by placing the oats and the solution in a glass fruit jar and shaking until the seed was uniformly discolored by the solution. The seed was then spread out in a thin layer to allow the carbon bisulphide to evaporate.

[2] Formaldehyde was applied by the spray method as described by Tapke, V. F., "Formaldehyde Seed Treatment for Oat Smuts." U. S. Dept. Agr. Misc. Publ. No. 21, 1928.

TABLE 6. EFFECT OF DUST TREATMENTS ON INCIDENCE OF SMUT ON FULGHUM OATS AND ON YIELD, MAIN EXPERIMENT STATION, 1931

Treatment	Smut infection from counts of 10 areas 22 inches in diameter				Threshing percentage	Yields per acre				Gains		
	Series			Average		Series			Average			
	A	B	C			A	B	C				
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels* [1]	*Per cent*
Check, nontreated	15.92	20.46	20.11	20.08	50.67	29.2	34.8	26.3	37.3	.....	.....	.....
	19.96	22.24	23.51	.....	.....	42.7	24.8	35.9	.....	.....	.....	.....
	20.46	20.11	18.36	.....	.....	34.8	26.3	50.6	.....	.....	.....	.....
Dubay No. 952 K	.09	.00	.00	.03	57.02	53.9	35.6	28.1	39.9	0.94	2.6	7.0
Corsican	.00	.00	.00	.00	55.54	50.9	37.8	34.7	41.2	3.31	3.9	10.5
Dubay No. 500 LL	.00	.96	.52	.49	54.54	48.0	40.5	38.8	42.4	5.68	5.1	13.7
Corona No. 174 E	3.02	2.37	2.91	2.77	56.48	52.7	35.5	40.6	42.9	7.32	5.6	15.1
Merko	18.94	20.32	19.89	19.72	54.60	37.3	36.7	34.4	36.2	.98	—1.1	— 3.0
Dubay No. 952 C	.00	.00	.00	.00	53.37	44.1	41.7	55.3	47.0	11.17	9.7	26.1
Corona Oat Dust	.00	.00	.00	.00	55.04	40.9	38.9	55.3	45.1	8.50	7.8	21.0

[1] These gains in this column were obtained without adjustment. There are no significant differences in yield.

Treated oats were planted in 1931 in one-tenth-acre plots on land that had been in corn for the 3 preceding years. Each treatment was repeated three times with the exception of the iodine treatment, of which there was only one plot. Seven checks were used, the last check in the first and second series appearing as the first in the series following. All seed for the 1931 tests was sown March 18, 1931, 2 days after treating. Soil moisture and temperature conditions remained favorable for the growth of oats throughout their growing period. Stand counts and counts of infected heads were made shortly before harvest. Using a wire hoop, 22 inches in diameter, 10 samples were taken at random from each plot. In certain cases, although these counts indicated that no smut was present, a careful survey of the plots revealed the presence of a very small number of smutted panicles. These were equivalent to a mere fraction of one per cent of the total number of panicles in the plot.

The results of the 1931 test are presented in Table 6. Theoretical yields of interpolated checks have been used as a basis for computing gain or loss from treatments over checks, and gains or losses without adjustment also are shown with percentage values.

A statistical interpretation of the yield data shows that the standard deviation of an individual plot yield, as determined by the check-plot method, is 11.66 bushels or 31.3 per cent. The standard deviation of the mean for three plots is 6.74. The difference between plot yields necessary for significance is $2\sqrt{2}$ 6.74 or 19 bushels, assuming that the treated plots are subject to the same error in bushels as the nontreated ones. According to this standard no significant differences in yield exist, due to the high variability of yields in the check plots. However, the reduction in the incidence of smut resulting from all treatments except Merko, which the manufacturers do not recommend for oats, is clear-cut and, on the whole, satisfactory. There appears to be little relation between the treatments and the ratio of grain to straw as expressed by the threshing percentage,[5] and no relation between treatments and stand could be noted.

The 1932 tests were planted March 19, 1932. The dust applications were made as in the previous year, and three plots from each lot of treated seed were planted. All seed was sown as soon as treated, with the exception of that treated with formaldehyde

[5] The threshing percentage represents the relation between the weight of threshed grain and the weight of bundles.

and that treated with iodine, which was planted 24 hours after treating. Five check plots were included.

The seed was obtained from one of the 1931 check plots in which about 20 per cent of the panicles were infected. Five areas on each plot and then five duplicate areas on the five check plots were counted and percentages of infection calculated. Unusually dry weather during the spring months resulted in short straw and a low yield of grain.

The percentage of infection on plots where nontreated seed was used was 19.25 per cent, which was not markedly different from that of the previous year (Table 7). All of the treatments controlled smut except the iodine treatment, which was not nearly as effective as in 1931, possibly because thorough coverage was not obtained.

On treated-seed plots there was a consistent, though not large, gain in yield, varying from 2.7 to 6.8 bushels, or from 12.9 to 32.5 per cent. These figures are from nonadjusted yields; no interpolations between check plots were made, because, due to amount of seed available, the plots varied in size. The gains averaged 4.3 bushels, or 20.55 per cent, on the plots where dust-treated seed was used, in contrast to a gain of only 17.70 per cent for the liquid-formaldehyde treatment.

The standard deviation of a single yield was 2.16 bushels, or 10.3 per cent, showing the variability to be only one-third as much as in 1931. The standard deviation of three plots was 1.25 bushels. Again using twice the square root of 2 multiplied by the standard deviation of three plots as a measure of significance, the result was 3.5 bushels, or the difference needed to establish significance. All treatments in 1932 except Dubay 1134, Dubay 952 K, and iodine gave significant differences in yield. The increased yields of certain dust treatments over the liquid-formaldehyde treatment suggest the possibility of stimulatory effects due to the treatment in addition to increases in yield from the control of oat smut. This has been noted by workers in other states, but sufficient data are not available from this study on which to base definite conclusions.

The results of the iodine treatment of oats are not included in Table 6, as only one plot was used in 1931. Counts of 10 areas selected at random, as in the case of the other plots, revealed no smut whatsoever in the iodine plot, and even a careful search of the whole plot revealed the presence of only the slightest trace of smut. The yield per acre computed from the iodine plot was

exceptionally high, but it is believed that soil differences may be responsible for part of this increase. In 1932 iodine gave much poorer control than did the other treatments, and yield increases were not significant.

1933-36 Studies

The data for 1931 and 1932 demonstrated clearly the efficacy of several treatments for the control of smut. From 1933 to 1936 the oat-seed treatments were conducted to determine whether there might be other beneficial effects from seed treatments on yield besides those resulting from the control of oat smut.

An effort was made to obtain an entirely smut-free source of oat seed in order that there would be no complications arising from the control or partial control of oat smut. Since such seed could not be found, it was decided to use Fulghum seed from treated plots of the previous year (1932) that were comparatively free of smut, and, for comparison, to use heavily smutted seed from nontreated checks. The nontreated plots had an average of 19.25 per cent smutted heads, whereas no smut was noted in the plots used as source of clean seed (Table 7). In the years succeeding 1933 there was a considerable increase in the percentage of smut occurring when nontreated seed from the checks of the previous year was used, so that by 1936 the incidence of smut rose on at least one nontreated plot to nearly 50 per cent. Seed from treated plots showing no smut the preceding season invariably showed some smut when no treatment was used. This may be attributed in part to thresher contamination, although oats from nontreated plots were always threshed last, and in part to the fact that the "smut-free plots" were actually never entirely free of smut.

The treatments used for the years, 1933-36, were:

(1) Smutted seed, nontreated.
(2) Smutted seed, formaldehyde spray.
(3) Smutted seed, 2 per cent Ceresan.
(4) Smutted seed, formaldehyde spray and 2 per cent Ceresan.
(5) Clean seed, nontreated.
(6) Clean seed, formaldehyde spray.
(7) Clean seed, 2 per cent Ceresan.
(8) Clean seed, formaldehyde spray and 2 per cent Ceresan.

The formaldehyde treatment is the modified formaldehyde spray method as previously described. Two per cent Ceresan was

TABLE 7. EFFECT OF DUST TREATMENTS, LIQUID FORMALDEHYDE, AND IODINE IN CARBON BISULPHIDE ON INCIDENCE OF SMUT ON FULGHUM OATS AND ON YIELD, MAIN EXPERIMENT STATION, 1932

Treatment	Smut infection from counts of five areas 22 inches in diameter						Yield per acre				Gains	
	Series					Average	Series			Average		
	A	B	C				A	B	C			
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Per cent*
Check, nontreated	21.6	18.2	27.9	20.0	14.7		23.5	23.3	20.1			
Duplicate 5 counts	17.3	20.8	17.5	20.5	14.0	19.25	18.6	18.8		20.9		
Dubay No. 1134	.0	.0	.4			.13	27.8	21.0	22.2	23.7	2.8	13.4
Dubay No. 500 LL	.0	1.3	.4			.57	24.8	24.8	23.5	24.4	3.5[1]	16.7
Dubay No. 952 K	.0	.0	.0			.00	25.5	23.1	23.7	24.1	3.2	15.3
Dubay No. 952 C	.0	.0	.0			.00	28.0	26.1	29.1	27.7	6.8[1]	32.5
Ceresan	.0	.0	.0			.00	28.5	23.5	25.1	25.7	4.8[1]	23.0
Corona Oat Dust	.0	.0	.0			.00	25.5	22.3	29.0	25.6	4.7[1]	22.5
Liquid formaldehyde	.0	.9	.0			.30	24.0	23.3	26.4	24.6	3.7[1]	17.7
Iodine	5.0	4.8	5.2			4.65	21.2	24.8	24.9	23.6	2.7	12.9
Duplicate		3.6										

[1] Significant differences

used at the rate of 3 ounces per bushel. When both formaldehyde and Ceresan were used, the former was applied first and the seed thoroughly aired before applying the Ceresan. The purpose of this combined treatment was first to eliminate as far as possible the factor of smut infection by use of formaldehyde, so that the effect of the Ceresan application might be interpreted more completely on the basis of its possible protective or stimulating effect rather than on the basis of smut control. All parts of the drill that come in contact with seed were sprayed with formaldehyde solution after planting nontreated seed, and all Ceresan-treated plots were planted last.

There were three series of treatments. The treated seed was planted in a randomized arrangement within the series except in 1934, when, due to a shortage of seed from heavily smutted plots, only one series of treatments of smutted seed was used. Smut counts were made by counting the heads in 10 circular areas, 22 inches in diameter, selected at random from each plot. A much greater number of heads were counted in 1936, since several entire drill rows from each plot were counted. Yield records were not taken in 1934, because the crop was destroyed by hail just as it was ready to harvest. Smut counts, however, were made before the hail occurred.

Yield differences were too variable to give any definite evidence that seed treated with formaldehyde and Ceresan (ethyl mercury chloride) gave any better yields than that treated with formaldehyde alone. No evidence of disease control other than the control of smut was evident. The results with respect to the incidence of smut are summarized in Table 8, and yield data are summarized in Table 9.

Nearly perfect control of smut was secured from the use of formaldehyde, 2 per cent Ceresan, and a combination of the two, regardless of whether seed was heavily smutted from checks of the preceding year or was smut-free seed from treated plots of the preceding year. These data and those of the 2 preceding years (Tables 6 and 7) show that practically perfect control of oat smut may be secured from the use of formaldehyde used as a "soak" or spray, by the use of formaldehyde dust, and by the use of various organic mercury compounds, particularly ethyl mercury chloride.

Nontreated seed from apparently smut-free plots failed to control smut completely, and gave an average of 6.8 per cent of smut in the 3 years in which it was used. Had it been used a

TABLE 8. EFFECT OF SEED TREATMENTS ON INCIDENCE OF SMUT IN FULGHUM OATS, MAIN EXPERIMENT STATION, 1933-36

Seed and treatment	Smut infection in 1933	Smut infection in 1934 [1]						Smut infection in 1935 [1]			Smut infection in 1936		
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Seed from treated plots													
Nontreated	2.76	3.10	5.42	8.7	9.1	8.2	6.2	.....	.....	.....	4.39	9.01	11.79
Ceresan	.00	.00	.00	.0	.0	.0	.0	.....	.....	.....	.22	.03	.03
Formaldehyde	.00	.00	.00	.0	.0	.0	.0	.....	.....	.....	.00	.00	.00
Ceresan and formaldehyde	.00	.00	.00	.0	.0	.0	.0	.....	.....	.....	.00	.00	.00
Smutted seed													
Nontreated	36.65	37.35	49.15	38.7	.....	.....	.....	47.10	47.50	47.90	32.39	40.79	40.05
Ceresan	.00	.00	.00	.4	.....	.....	.....	.00	.00	.02	1.17	.66	.34
Formaldehyde	.33	.00	.00	.0	.....	.....	.....	.03	.02	.06	.00	.03	.03
Ceresan and formaldehyde	.00	.00	.00	.0	.....	.....	.....	.00	.00	.00	.00	.00	.00

[1] Because of shortage of seed only one plot of smutted seed was planted in 1934. In 1935 no seed from treated plots was available due to hail damage in 1934.

TABLE 9. YIELD OF FULGHUM OATS UNDER VARIOUS METHODS OF SEED TREATMENT FOR OAT SMUT, MAIN EXPERIMENT STATION, 1933 AND 1935-36

Seed and treatment	Acre yields, 1933			Average, 1933	Acre yields, 1935			Average 1935	Acre yields, 1936			Average, 1936
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Seed from treated plots												
Nontreated	25.6	22.1	13.9	20.50	.....	.....	.....	.....	20.3	16.7	15.2	17.4
Ceresan	25.5	11.7	17.2	18.10	.....	.....	.....	.....	25.2	21.5	26.1	24.3 [1]
Formaldehyde	23.8	16.3	13.1	17.70	.....	.....	.....	.....	21.8	19.1	19.4	20.1
Ceresan and formaldehyde	20.5	21.2	6.7	16.10	.....	.....	.....	.....	25.2	18.5	25.5	23.1
Smutted seed												
Nontreated	13.5	10.0	6.4	9.97	13.7	9.5	18.7	14.0 [2]	16.7	12.4	11.5	13.5
Ceresan	28.5	20.0	9.3	19.30 [1]	26.4	12.1	15.5	18.0	22.4	19.4	24.9	22.2 [1]
Formaldehyde	24.8	18.6	13.6	19.00 [1]	18.6	17.0	18.5	18.0	23.9	20.6	25.8	23.4 [1]
Ceresan and formaldehyde	17.5	13.3	15.5	15.40 [1]	23.3	14.2	20.3	19.3	21.8	17.3	24.6	21.2 [1]

[1] These averages show significant gains.

[2] In 1935 treatments apparently caused a gain of 4 to 5 bushels, or 28 to 37 per cent, but, because of the small number of plots, these gains are not statistically significant.

second year without treatment, it seems certain that a much greater incidence of the disease would have resulted. It should be noted that the so-called smut-free plots used as a seed source were never entirely free, since, by diligent search, a few smutted heads could always be found. Furthermore, thresher contamination may easily be a factor in contaminating the seed from treated plots, since no attempt was made to disinfect the separator before using it.

The seed from a 20 per cent smutted field in 1931 was used in 1932, and gave practically the same amount of smut. During the 4 succeeding years the incidence of smut ranged from 36 to nearly 50 per cent, but there seemed to be no tendency for it to increase in a cumulative manner beyond that point.

Yield records were so variable from year to year and from plot to plot that there is little basis for comparing the effect of various chemical treatments on yields with each other. However, when seed from heavily smutted plots was used without treatment, resulting in high incidence of smut, yield reductions were striking and nearly in direct proportion to the amount of smut present.

Summary and Conclusions

Certain dust treatments, employed for the years 1931 and 1932, gave excellent control of loose smut of oats, whereas others gave only a fair degree of control or were ineffective. In 1932 the dust treatments compared favorably with the liquid-formaldehyde treatment.

Iodine, in 10 per cent solution in carbon bisulphide, applied at the rate of one-half ounce of elemental iodine per bushel, gave nearly perfect control of loose smut of oats in 1931, but was much less effective in 1932.

None of the treatments employed appeared to affect the stand or to have any marked effect on the ratio of straw to grain, as expressed in the threshing percentage.

Variability in the check-plot yields in 1931 was so great that statistically significant differences were not made. In 1932 less variability was shown and the gains, for the most part, attained significance.

During the period, 1933 to 1936, a study was made of the effect of various treatments for the control of oat smut on yields of grain.

Fulghum oats from plots that were badly affected with loose smut the preceding season were planted each year through

1936. Beginning with about 20 per cent of smutted panicles in 1932, the incidence of smut increased to nearly 50 per cent, but showed no tendency to increase in a cumulative manner beyond that point.

Seed from apparently smut-free plots when not treated invariably showed from 3 to nearly 12 per cent of smutted panicles. There was no tendency for smut to disappear completely when seed from smut-free treated plots was used.

Almost perfect control of smut was obtained when either the formaldehyde spray method or ethyl mercury chloride dust was used. Work of the first 2 years indicated that, in addition to various experimental organic mercury dusts, the formaldehyde-dip method and formaldehyde dust (Corona Oat Dust) also gave practically perfect control of oat smut.

Although yield increases were essentially in proportion to the reduction in smut incidence when heavily smutted seed was used, differences between results from various treatments were not sufficient to indicate that any of the treatments were more efficient than others in their effects on yields of oats.

Combined treatments using first a formaldehyde spray and then ethyl mercury chloride dust with either heavily smutted or clean seed gave no evidence of beneficial results from the use of ethyl mercury chloride dust other than those to be ascribed to the control of smut. No evidence of stimulatory effects or benefit on yields from the control of other seed- or soil-borne organisms was secured. It thus appears that cost, ease of application, and freedom from danger of seed injury are, in the final analysis, the determining factors when selecting a seed treatment for oats.

BARLEY-SEED TREATMENTS

The planting of barley is becoming more common in northwestern Arkansas, and observations have indicated that barley smut of both the loose type and covered type is common and often destructive.

Methods

Seed treatments were conducted during the period, 1936-38. The Missouri Beardless variety was used, and the original seed was obtained from a badly smutted field near the Main Experiment Station farm. Seed from nontreated checks was used in succeeding years. Both covered smut and loose smut were present, but no attempt was made at any time during the study to differ-

TABLE 10. EFFECT OF SEED TREATMENTS ON INCIDENCE OF SMUT AND ON YIELDS OF MISSOURI BEARDLESS BARLEY, MAIN EXPERIMENT STATION, 1936-38

Treatment	Heads counted			Infected with loose smut			Infected with covered smut			Yields per acre		
	1936	1937	1938	1936	1937	1938	1936	1937	1938	1936	1937	1938
	Number	*Number*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Bushels*	*Bushels*	*Bushels*
Check	9,354	9,774	10,725	10.630	7.57	2.20	0.900	11.13	6.43	11.9	28.5	17.4
New Improved Ceresan	8,622	8,202	10,084	9.360	3.66	.78	.046	.02	.03	19.9	28.0	12.4
Hot water	7,949	10,432	9,091	.000	.39	.04	.113	.52	5.31	27.0 [1]	32.4	12.7
Formaldehyde	9,231	5,745	8,713	9.030	5.73	.98	.011	.24	3.09	24.9	26.8	16.0
Check	8,714	9,144	8,100	9.730	6.68	2.35	1.280	6.45	5.65	20.8	26.3	13.5
New Improved Ceresan	8,889	9,876	11,269	8.720	3.69	.67	.022	.00	.01	21.9	31.0	13.5
Hot water	7,565	10,499	6,563	.013	.66	.21	.040	.75	8.41	25.7 [1]	36.7	12.9
Formaldehyde	8,313	5,285	6,210	10.690	4.37	.00	.000	.68	5.29	25.7	30.8	12.9
Check	9,356	7,543	6,734	12.130	6.54	4.63	3.630	6.51	13.49	24.9	32.3	16.9
Average (unweighted)												
Check (9)		8,827			6.94			6.160			21.39 [2]	
New Improved Ceresan (6)		9,490			4.48			.021			21.11	
Hot water (6)		8,683			.22			2.520			24.57	
Formaldehyde (6)		7,249			5.38			1.550			22.85	

[1] Hot-water treatment barely significant in 1936.
[2] No significant differences in any of the average yields.

entiate between the two species of loose smut, caused by *Ustilago nuda* and *U. nigra* Tapke *(6)*, respectively. Since Missouri Beardless is a winter-type barley, seed was sown in the fall, generally about October 10. The land had been planted previously to cotton, corn, and oats, but no barley had been planted for at least 13 years. Seed treatments used were the hot-water method, the formaldehyde-dip method, and New Improved Ceresan dust (ethyl mercury phosphate).

Seed to be treated by the hot-water method was first presoaked in water at room temperature for 6 hours and was then brought to 120° F. for one minute, after which it was immersed in water at 126° F. for 13 minutes, and finally cooled under the tap as rapidly as possible and spread out to dry.

The formaldehyde treatment used is described in U.S.D.A. Miscellaneous Circular 219. One pint of commercial formaldehyde was added to 40 gallons of water, and the solution used at ordinary room temperature. Seed was immersed in this solution, taking care to thoroughly wet the grain, and the grain was then thoroughly drained and spread out to dry overnight before planting.

New Improved Ceresan was applied at the rate of one-half ounce per bushel with the same equipment used for treating oat seed. The drill was disinfected with formaldehyde before planting, and all treatments with New Improved Ceresan were planted last to avoid the possibility that seed might be contaminated with dust adhering to the drill.

Each treatment was repeated twice in the experimental field, and there were three nontreated checks. Smut counts were made by selecting at random one-fourth of the drill rows in each plot and counting the total number of heads, at the same time removing all smutted heads for later counting. Inspection of each row was continued until no more smut could be found, since experience showed that loose smut is easily overlooked. In 1936 barley-stripe, (caused by *Helminthosporium gramineum* (R.) Erick.), was present in small amounts, but disease readings on it were not taken. The results of the 3 years' test are presented in Table 10.

1936-38 Studies

There is some indication that the hot-water treatment reduced the stand somewhat, particularly in 1936, and in 1937 definite injury resulted from the formaldehyde treatment owing to the delay in planting. The stand was very much reduced and the

growth was much retarded during the early part of the season. However, reduction in stand seemed not to have any clear-cut effect on yields.

In 1936 the incidence of covered smut was low, and all treatments gave nearly perfect control of this type of smut. In 1937 the incidence of covered smut had increased considerably over that of the preceding year. There were also slight increases in the amount of covered smut in the hot-water and formaldehyde plots. In 1938 the most noticeable feature was the failure of both hot water and formaldehyde to control covered smut, although New Improved Ceresan gave almost perfect control.

In 1936 hot water controlled both loose and covered smut almost perfectly. Slight reductions in the incidence of loose smut in the Ceresan- and formaldehyde-treated plots suggest the presence of a small amount of the seedling-infection type of loose smut that surface treatments might be expected to control. Since barley had not been planted on this land or nearer than one-fourth of a mile for several years, no other source of infection need be considered for the 1936 results except the seed itself.

In 1937 the incidence of loose smut in the nontreated checks was lower than in 1936, and in 1938 it was even less than in 1937. The striking feature of these results is the remarkable control of loose smut by New Improved Ceresan in both years, indicating that a considerable portion of the loose smut in these 2 years was of the seedling infection type. Formaldehyde also controlled loose smut to a considerable extent but not as well as New Improved Ceresan. Hot water, although giving high reduction in the incidence of loose smut, failed to give perfect control.

Discussion of Results

The results of these seed treatments suggest that the problem of barley smut control, under the conditions of this experiment, is more complicated than was originally suspected. The failure of the hot-water treatment to give control of covered smut in 1937, and particularly in 1938, indicates very strongly that infection from soil contamination must have been a factor in these years. Formaldehyde likewise gave imperfect control, especially in 1938, and this again points to soil contamination as a factor. The fact that New Improved Ceresan gave excellent control of covered smut throughout the 3-year period suggests that the fungicidal dust adhering to the seed may give considerable pro-

tection against infection from *U. hordei* in the soil. Since formaldehyde may be largely dissipated before planting, little effect on soil-borne smut spores need be expected from it.

From the standpoint of loose smut, it seems certain that both the seedling and blossom infection types of smut were present, since very marked control was secured by surface treatments that have no effect on the internal infection of *U. nuda*. The further fact that hot water gave only partial control of loose smut suggests the possibility again of soil contamination with spores of loose smut of the seedling infection type, which was controlled to a considerable extent by New Improved Ceresan.

Soil contamination with spores of bunt of wheat is, of course, a serious problem in the Inland Empire country of Washington, Oregon, and Idaho. The problem in the Inland Empire country arises from the fact that conditions are favorable for the survival in a viable condition of bunt spores and for their dissemination, due to the fact that harvest and seeding periods are only a few weeks apart, that dry weather prevails during the interim, and that bunt spores are widely disseminated by prevailing winds in "smut showers." In Arkansas barley is harvested in June and planted the following October. The data presented herewith suggest very strongly that soil contamination with spores of both *U. hordei* and *U. nigra* occurred in Arkansas during the two seasons mentioned above, and that ethyl mercury phosphate, employed as a fungicidal dust, gave a high degree of control of smut infections from the soil. Further work more specifically designed to test this hypothesis is needed.

The data on the effect of barley-seed treatments on the yield of barley are unsatisfactory and conflicting. In 1936 increases from the use of the hot-water and formaldehyde treatments seemed fairly definite, but for later years the data are very conflicting. In 1937 all yields were comparatively high but unfavorable weather conditions in the spring of 1938 resulted in very short straw, many poorly filled heads, and decidedly inferior yields. Due to unequal soil conditions, two of the check plots in 1938 gave considerably better yields than any of the treated plots. The averages for the 3-year period show definite gains for the hot-water treatment, some gains for the formaldehyde treatment, and no gain for the Ceresan. More trials on more uniform soil appear necessary before one can draw any definite conclusions with respect to the effect of the seed treatments used on the yield of barley.

Conclusions

Barley-seed treatments on the Missouri Beardless variety, using the hot-water method, the formaldehyde-soak method, and ethyl mercury phosphate dust, were conducted during 1936, 1937, and 1938.

Covered smut *(Ustilago hordei)* and loose smut *(U. nuda)* were present. Loose smut was controlled to a considerable degree by both the formaldehyde-soak and ethyl mercury phosphate dust treatments, as well as by the hot-water method. Partial control of loose smut of barley by surface treatment indicates that part of the loose smut was caused by *U. nigra.*

In 1937 and especially in 1938 there were definite indications that, in addition to infection from seed-borne smut, infection also resulted from spores arising from the previous crop and remaining over summer in the soil. There was indication that spores of both *U. hordei* and *U. nigra* survived over summer in the soil.

There were strong indications that ethyl mercury phosphate dust gave definite protection against infection from soil-borne spores of both *U. hordei* and *U. nigra,* as well as from seed-borne spores of these fungi. The hot-water treatment and the formaldehyde soak-method afforded protection against seed-borne infection only. No significant differences in yields were found.

The extreme variation in yield among the checks indicates that soil inequalities were probably the greatest factor causing differences in yields.

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